



E/CONF.39/A/23

27 Sept. 1962

ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item : A. 3. 4. 1

South Africa

THE POLLUTION POTENTIAL OF SURFACE RUN-OFF
AND ITS SIGNIFICANCE IN WATER MANAGEMENT

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REPUBLIC OF SOUTH AFRICA
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1. Introduction

(a) The quality of surface run-off, which is of utmost significance in long-range planning and storage of raw water or water conservation, is profoundly affected by the present-day growth in populations and the resultant intensification of road construction and agricultural projects; the establishment of residential and recreational areas; inadequate sanitation in built-up areas; the pollution of the atmosphere with the solid and gaseous debris of combustion, floating dust, bacterial life and fungi; the accumulation of industrial wastes; the control of pests and weeds; and the rapid development of new chemicals and radioactive materials^{4, 6, 7, 8}.

(b) In the past, water conservation and development were mainly concerned with water volume, while little consideration was given to the debilitating effects of pollution. Water conservation does not lie in the hoarding of water in lakes, reservoirs and related structures. Conservation means the use of water in a way that will benefit the greatest number of people for the longest possible time. Pollution is the greatest enemy of water conservation since it imposes an immediate serious limitation on the beneficial use and re-use of water supplies. It follows that, to meet the challenge of the ever increasing demand on available water supplies, it is imperative that surface run-off pollution be effectively controlled.

(c) A prerequisite for the planning of pollution prevention programmes aimed at minimizing the pollution potential of surface run-off, is to collect,

through research, the basic information necessary for identifying specific geographic entities in terms of the pollution potential of their surface run-off. The results thus obtained would provide a sound scientific basis for formulating remedial measures and/or for making valid predictions about areas as yet undeveloped.

2. The effect of pollution on streams, lakes and reservoirs

(a) Surface waters, which constitute by far the most important source of public water supply, receive a large variable load of organic material, mineral matter (including silt) and bacteria carried in surface run-off. The bulk of the polluting matter accumulates in rivers, reservoirs and lakes to form bottom deposits and the rest remains in solution or suspension in the water zone. Both the bottom deposits and the supernatant water are zones of active biological and biochemical activity and play an important rôle in the process of self-purification. The specific geographic composition of the catchment area of the receiving streams is intimately related to the nature of the polluting material carried in the surface run-off, which in turn controls the particular biological activity pertaining to the stream and which can cause serious deterioration in the quality of the water: algal blooms can have serious effects on the taste and odour of the purified water; toxic substances can be responsible for major fish kills; the presence of detergents in concentrations as low as 0.6 mg/l impairs the rate of re-oxygenation of natural waters; heavy intermittent pollution by organic substances gives rise to conditions alternating between aerobism and anaerobism which can result in the production of toxic and noxious substances; and increased mineral contributions are responsible for variations in the corrosive or encrustative properties of the water supplies. It must also be borne in mind that pollution, whatever its form and nature may be, imposes a serious limitation on the usefulness of the natural water resources and constitutes a danger to public health. There appears to be a significant correlation between endemic goitre and the pollution of water supplies by organic materials.

(b) During the initial stages of pollution prevention and conservancy operations, attention throughout the world was mainly focussed on obviating the flagrant nuisances of pollution. As a result of a century of research and technological development, the processes of sewage and industrial effluent purification are to-day sufficiently advanced to provide water engineers with a sound basis for the implementation of control measures to protect surface water supplies. The relatively high concentrations of eutrophying compounds present in sewage effluents, however, are still a source of great concern. In contrast to this the increase in the pollution potential of surface run-off has proceeded unchallenged and has assumed proportions which constitute a serious threat to the protection and conservation of surface water supplies. Considerable loads of polluting substances, carried by surface run-off, are finding their way into the main drainage systems.

3. The pollution potential of surface run-off

(a) Surface run-off from agricultural areas:

- (i) The diverse land-use activities encountered in agricultural areas and the extensive application of fertilizers, insecticides and herbicides are all factors which may cause serious pollution of surface waters.
- (ii) In pollution studies carried out on the Hallwilersee, Switzerland, Ambühl¹ has demonstrated that the load of nutrients derived from surface run-off and seepage from cultivated lands is equivalent to that of the sewage inflow from the entire catchment area.
- (iii) In the case of the Wemmershoek Dam, near Cape Town, eutrophication of the waters in the storage dam by surface run-off from an area, formerly used for agricultural purposes, gave rise to the occurrence of chironomid larvae in the City's reservoirs. In 1960 investigations by Cholnoky and Claus² showed that a comparatively rich phytoplankton which served as a nutrient for the chironimids was found in the storage dam. It was also shown that the nitrogen compounds reaching the storage dam from drainage of the above area were responsible for the weak mesotrophic conditions of the stream and the dam as well as for the comparatively rich production of phytoplankton and zooplankton.
- (iv) Mineral enrichment of surface waters by irrigation can assume alarming proportions as is shown in the case of the Vaal-Hartz irrigation scheme⁷. The entire flow of the Hartz River, estimated at 50 million gallons per day (m.g.d.) during the dry season, consists of drainage from the irrigation scheme. The intake volume from the Vaal River, is of the order of 250 m.g.d. Mineral enrichment in the drainage water, expressed as multiples of the concentrations of the individual constituents of the intake water is as follows: Total dissolved solids - 3.47; Total alkalinity (as CaCO₃) - 2.78; Total hardness (as CaCO₃) - 3.07; Magnesium hardness (as CaCO₃) - 2.68; Calcium hardness (as CaCO₃) - 3.58; Sodium (as Na) - 4.76; Potassium (as K) - 0.6; Chloride (as Cl) - 5.50; and Sulphates (as SO₄) - 16.66.
- (v) According to Cottam³ there is much evidence that some of the chemicals used as pesticides and herbicides are entering water supply systems and that it may be dangerous to ignore the effects of small quantities of these substances in the water supplies.
 - a. Herbicides, such as 2,4-D, taint drinking water if present in concentrations as low as 1 part in 100 million and clearly, care must be taken to avoid even traces of such chemicals entering water supplies⁵.
 - b. A survey of fish kills in America showed that in three cases, with the highest percentage of fish killed, the cause was industrial poisons of which pesticides accounted for 38% of the cases. The infinitesimal amount of 0.6 parts per billion of chlorinated hydrocarbons will kill 50% of test blue gills in 96 hours³.

- c. Within a few days of spraying a forest with 3 gallons per acre of liquid insecticide in the Harrismith area, Orange Free State, the entire water purification works was brought to a standstill owing to contamination of the water supplies.
- (vi) The housing of animals in partly roofed yards presents problems of disposal of surface run-off contaminated with manure.
 - a. Reports in Notes on Water Pollution⁵ show that on a basis of B.O.D., the drainage from cowsheds where cows were brought in twice daily for milking, produced an effluent equivalent to 89 gallons average crude domestic sewage per cow per day. The daily output of dung from a single cow may be equal to the faeces from some 50 persons⁵.
 - b. Piggery effluents are often exceedingly strong. At a piggery housing 1500 pigs, it was calculated that the B.O.D. load per pig was 0.243 lb/day - approximately twice that of average crude domestic sewage per person per day⁵.
- (vii) The effluent produced by ensilage of one ton grass (17.8% dry matter) in a covered silo, has been reported to be equivalent in polluting character to 12,000 gallons domestic sewage⁵.
- (viii) Soil erosion, enhanced by overgrazing, veld fires, monocultural practices and ploughing of hills, is chiefly responsible for the heavy silt loads carried by run-off water. Apart from the serious siltation of dams and reservoirs, the colloidal clay and organic material have a deleterious effect on the beneficial biochemical reactions which should take place during storage of raw water.
- (b) Surface run-off from residential and industrial areas
 - (i) Surface run-off from residential and industrial areas may contain both organic and inorganic substances. In the former case the pollution may seriously interfere with the self-purification properties of the receiving stream.
 - (ii) Although the pollution loads carried by surface run-off from the above areas have not as yet been studied in detail, the results obtained by Wilkinson, 1961⁸, on the run-off from a housing estate are very illuminating. The housing estate covered an area of 611 acres and accommodated an estimated population of 12,500 with about 8 houses per acre. From the results obtained it was estimated that the total weight of polluting matter actually discharged with the surface water to the river would be equivalent, on the basis of suspended matter, to 209 million gallons per year.
 - (iii) The total organic and mineral loads from mine, ash and domestic dumps can vary considerably depending on their permeability, areal distribution and the intensity of rainfall. However, a tentative estimate of the mineral load, based on a unit area of one square

mile dump area and a rainfall of 30 inches per annum, approximates 2000 to 3000 tons per year (according to Stander⁷ in 1962).

3. The significance of surface run-off pollution in water management

- (a) Water management and comprehensive planning of catchment development hinge on three basic factors: available and assured supply; storage capacity; and the demand on available supplies by various competing users. The balance between these three main elements constitutes the "water budget" of the particular hydrologic system and variations in the balance caused by man's use of the water are the key factors to be determined in judicious exploitation of the water resources.
- (b) Man's use of water may be defined in terms of nett and gross consumption. Nett consumption, that is, the amount of water permanently removed from the system, is effected by evapotranspiration, use by crops and other vegetation, industrial product consumption, disposal of wastes and storm-water into the sea and exportation of water to other catchments. Gross consumption is the total amount withdrawn and includes the nett consumption plus the amount returned after use to the specific hydrologic system.
- (c) The nett consumption usually comprises only a small fraction of the gross consumption, that is, a major portion of the water delivered to cities and industries is returned to the streams and rivers or percolates into the ground. The water thus returned can be used over and over again if it is not polluted or if appropriate measures are adopted to combat and eliminate pollution. It follows that if the quality of the water is not impaired it can be re-used almost indefinitely; on the other hand, deterioration of the quality of the water accounts for most of the nett consumption for the simple reason that badly polluted waters cannot be used again. Some elements of nett use, such as evaporation and transpiration by crops cannot be arrested easily, while pollution can be prevented provided that man is willing to pay the price.
- (d) Surface run-off pollution could be minimized to a great extent if town planners, nature and soil conservation authorities would co-operate in an attempt to transform the smaller rivers, streams and dams into recreational centres instead of ignoring their present abuse, thus allowing them to become channels for garbage and dumps for rubbish.
- (e) Two basic policies are involved in the control of stream pollution: first, the determination of possible uses and the quality tolerances required for such uses; second, the relation of these intended uses to the probability of drought flows. Decision as to these two policies includes, in addition to technical determinations, consideration of practical economic factors.
- (f) The following courses of action may therefore be adopted:
 - (i) The development of studies to determine the pollution potential from various geographic entities.
 - (ii) The inclusion, in catchment development programmes, of a full and

complete report on the effect surface run-off will have on municipal water supplies located downstream.

- (iii) The encouragement of unified planning for optimum use of water resources.

(g) Remedial measures

- (i) Pollution abatement becomes most difficult in streams with small intermittent flow. The encouragement of pools in such streams will, therefore, tend to retard erosion of the river bed; reduce the weight of solids discharged; provide reserves during times of scarcity; favour a wide range of velocities; and promote the fishing values of the stream.
- (ii) Under favourable topographic conditions the only economic solution to the problem, apart from imposing restrictions on the activities obtaining or liable to develop in a specific catchment area, is the impoundment of the surface run-off, from highly polluting areas, in maturation ponds, recreation dams or lakes, which may serve to prevent siltation of the main reservoirs and assist in the removal of phosphorus, nitrogen and organic carbon, the all important nutrients in lake fertilization.

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